PATENT SPECIFICATION

DRAWINGS ATTACHED

122

892,962

Date of Application and filing Complete Specification Dec. 2, 1958.

No. 38853/58.

Application made in Netherlands on Dec. 5, 1957.

Complete Specification Published April 4, 1962.

Index at acceptance:—Classes 64(3), S4C; and 7(1), C.

International Classification:—F25h. F02g.

COMPLETE SPECIFICATION

Improvements in or relating to Heat Exchangers

We, N.V. PHILIPS GLOEILAMPENFABRIEKEN, a limited liability company, organized and established under the laws of the Kingdom of the Netherlands, of Emmasingel 29, Eindhoven, Holland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be partciularly described in and by the following statement:—

This invention relates to heat exchangers comprising an annular main chamber formed between substantially cylindrical inner and outer walls in which chamber two media are kept separated and are in heat exchanging contact, and to hot-gas reciprocating apparatus embodying such heat exchangers. Known heat exchangers of this kind have a limitation in that they must be surrounded by insulating jackets which occupy a comparatively large amount of space so that they become comparatively bulky. In addition, the manufacture of a known heat exchanger consisting of tubes is complex since the tubes must be connected to supply and discharge ducts for the media with a high degree of accuracy.

According to the invention there is provided a heat exchanger comprising an annular main chamber formed between substantially cylindrical inner and outer walls and housing identical closely-spaced metal plates each extending substantially throughout the length of the main chamber having overlapping off-set end portions each secured at one end to the inner wall and at the other end to the outer wall, supply and discharge ducts for media extending in the longitudinal direction of the main chamber being formed between the overlapping off-set end portions of the plates adjacent the inner wall at one end of the plates and between the overlapping off-set end portions adjacent the outer wall at the other end of the plates, media in further ducts formed between portions of the plates intermediate the end portions being in heat exchanging contact with one another through the plates, in which the further ducts are formed by projections on the plates in the form of ribs which extend substantially at right angles to the longitudinal direction of the supply and discharge ducts.

The media may be liquids and/or gases.

An advantage of this construction consists in that the heat exchanger need not necessarily be provided with an outer insulating jacket. Furthermore the construction and manufacture of the heat exchanger according to the invention is simpler than is the case with a known heat exchanger of this type, because use is made of a number of identical plates which by their shapes and mutual disposition constitute not only the heat exchanging ducts but also the supply and discharge ducts for the media. In mass manufacture of identical heat exchangers use can be made of sheet material which is cut to the same sizes and subjected to a bending operation such that the plates obtained all have the required shape. The bent plates are then mounted in an assembling jig and connected to one another at the required points, for example by spot welding or soldering. The projections with which the plates are provided and which serve to space the plates apart by the required distances can be formed in sheet material by rolling during the above-mentioned bending operation.

In a cross-section of the heat exchanger taken at right angles to the longitudinal direction of the main chamber the intermediate portion of each plate may extend substantially at right angles to radii of the inner and outer walls. The advantage is thus obtained that the ducts in which the media are in heat exchanging contact with one another, can be made much longer than if the intermediate portions extend substantially radially. In addition the plates according to the invention have the important advantage that, without the plates having to be provided with comparatively complicated longitudinal profiles, a heat-

3A

exchanger, when provided with an internal combustion chamber and made up from such plates has the property that its inner parts are comparatively flexible with respect to the outer parts so that through a comparatively small radial distance temperature differences of a few hundreds of degrees Centigrade can occur without giving rise, in the operation of the heat exchanger, to impermissible thermal stresses in the material.

The intermediate portions of each plate may be shaped substantially according to an Archimedian spiral. The advantage is thus obtained that the cross-sectional area of each duct formed between the intermediate portions of plates is substantially constant throughout its length.

Hereinbefore it is described that at the inner and outer circumferences of the heat exchanger, owing to the provision of the overlapping offset end portions of the plates, ducts are produced which serve as supply and discharge ducts for the media. As a rule, the heat exchanger is used so that the supply and the discharge of each of the media to and from each of these ducts take place at different ends of the heat exchanger. This may involve that both adjacent the inner and adjacent the outer walls of the heat exchanger at both ends orifices leading to or from the ducts are alternately open or closed. Each end face of the heat exchanger may be provided with at least one substantially flat ring which is disposed over orifices leading to or from the supply and discharge ducts, alternate orifices being open and closed by alternate apertures or solid parts in the ring respectively. Such rings can be simply made from sheet metal by punching.

The metal plates may comprise sheet material provided with fold lines at the extremities of the intermediate portion of each plate, an adjoining bent portion and/or an adjoining end portion diverging or converging so that the supply and discharge ducts at the inner and/or outer walls of the heat exchanger are alternately closed at either end face of the heat exchanger.

The heat exchanger in accordance with the invention is particularly suited for use in combination with a hot-gas reciprocating apparatus. The term "hot-gas reciprocating apparatus" is to be understood to mean an apparatus in a closed chamber of which a medium is alternately compressed and expanded by the movement of pistons. This compression and expansion take place at different temperatures. If the hot-gas reciprocating apparatus is a hot-gas engine, the compression takes place at the lowest temperature and the expansion at the highest temperature, the engine being provided with a source of heat for supplying thermal energy to the medium at a comparatively high temperature. This heat source is ignited in a combustion chamber, the heat exchanger in accordance with the invention being advantageously used as a combustion air preheater in which the exhaust gases heat the combustion air supplied to the burner. When so used the heat exchanger in accordance with the invention is particularly advantageous since it is capable of expanding at the inner wall while the outer wall substantially retains its initial diameter in spite of the large temperature differences between the inner and outer walls of the heat exchanger. Furthermore the outer wall of the heat exchanger need not be surrounded by an insulating packet. In the known constructions this jacket frequently has an outer diameter of such size that the distance by which other machines or engines must be spaced apart from the engine with which the heat exchanger is associated, is determined by this outer diameter and not by the greatest transverse dimension of said associated engine. In a hot-gas reciprocating engine equipped with a heat exchanger in accordance with the invention, the outer diameter of the latter is not of importance.

In order that the invention may readily be carried out, embodiments thereof will now be described with reference to the accompanying diagrammatic drawings, in which:—

Figure 1 shows a cross sectional view in with the invention which encloses a com- with the invention which encloses a conbustion chamber for heating the head of a hot-gas engine, the cross sections of the separate plates of the heat exchanger being omitted for the sake of simplicity;

Figure 2 is a plan view of the heat exchanger shown in Figure 1 in which three plates are shown;

Figure 3 is a perspective view on an enlarged scale of the ends of three adjacent plates as used in the heat exchanger and also the relative disposition of the plates;

Figure 4 is a perspective view of a slightly modified profile for the plates used in the heat exchanger in accordance with the invention, and

Figure 5 is a view of the inside of a modified embodiment of the heat exchanger in accordance with the invention in which fold lines between intermediate portions, bent portions and edge parts converge, the edge parts being omitted.

In Figure 1, a head of a hot-gas reciprocating engine encloses a hot space 1a, the volume of which is periodically changed due to the movement of a piston-shaped body 2 which acts as a displacer. The upper wall of the head 1 comprises a plurality of apertures 3 arranged on a circle or circles, one leg of a substantially hairpin-shaped heating tube 4 being connected to each aperture. The other end of each heating tube 4 extends along

892,962 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

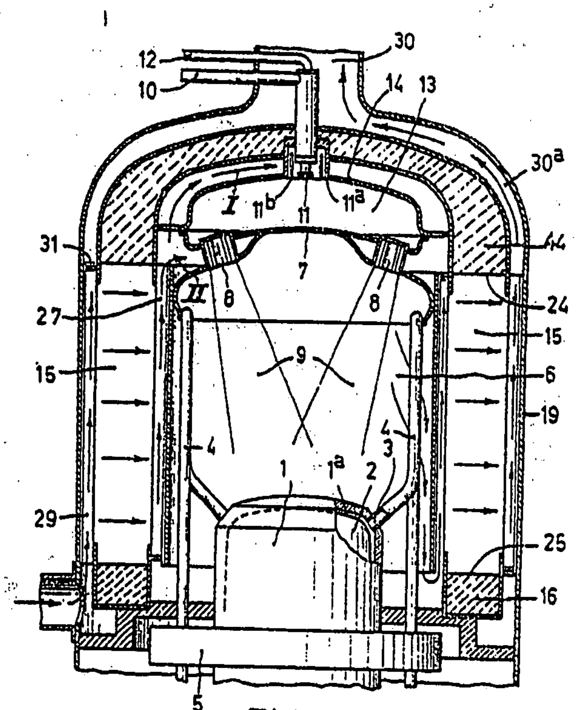


FIG.1

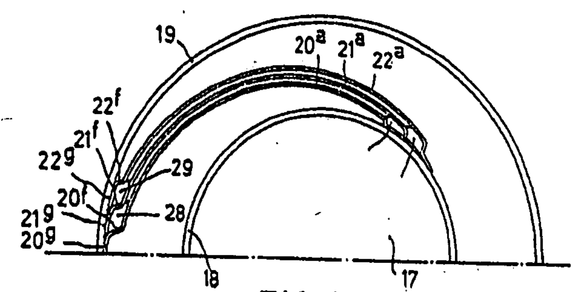


FIG.2

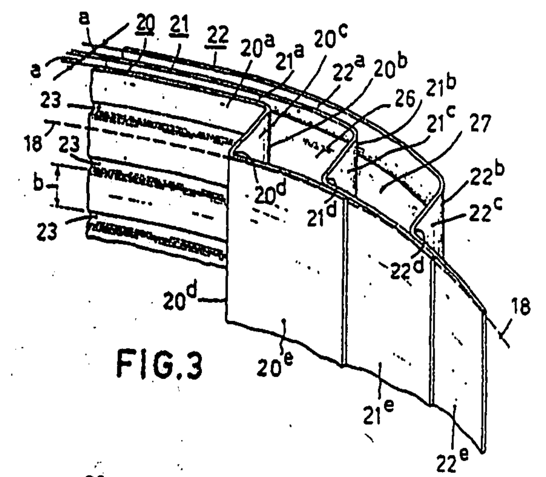


FIG.3

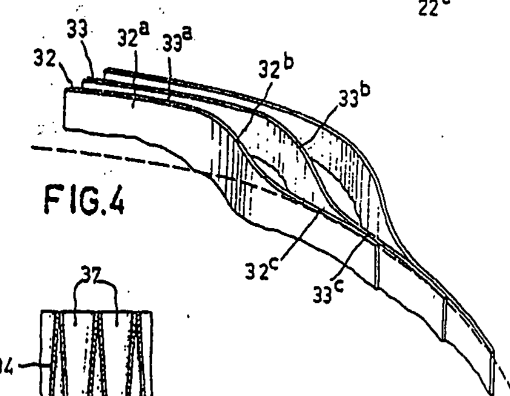


FIG.4

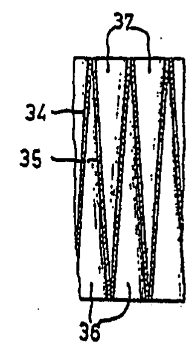
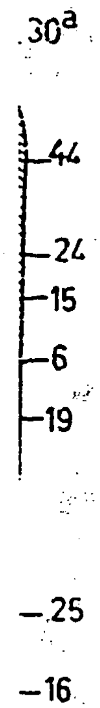


FIG.5



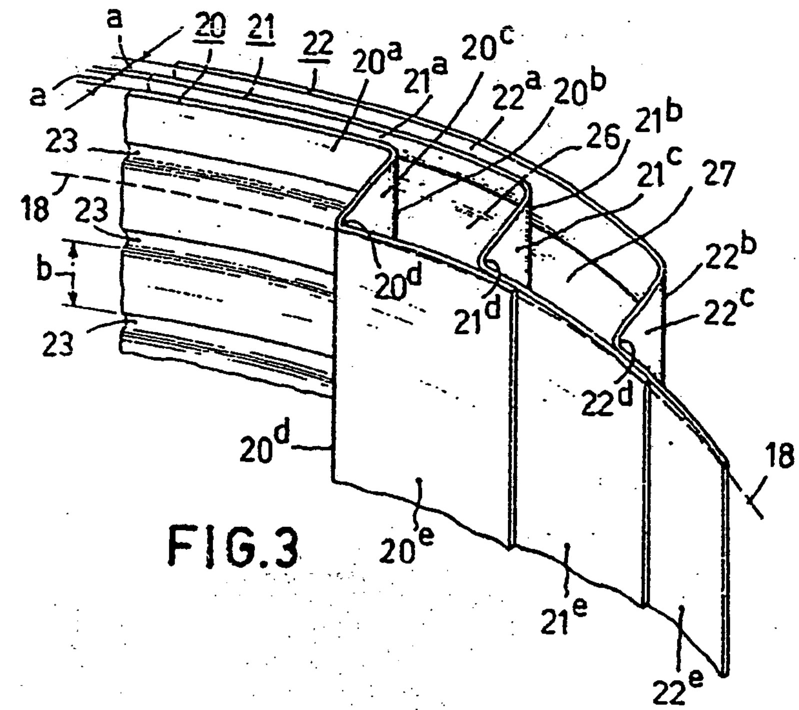


FIG.3

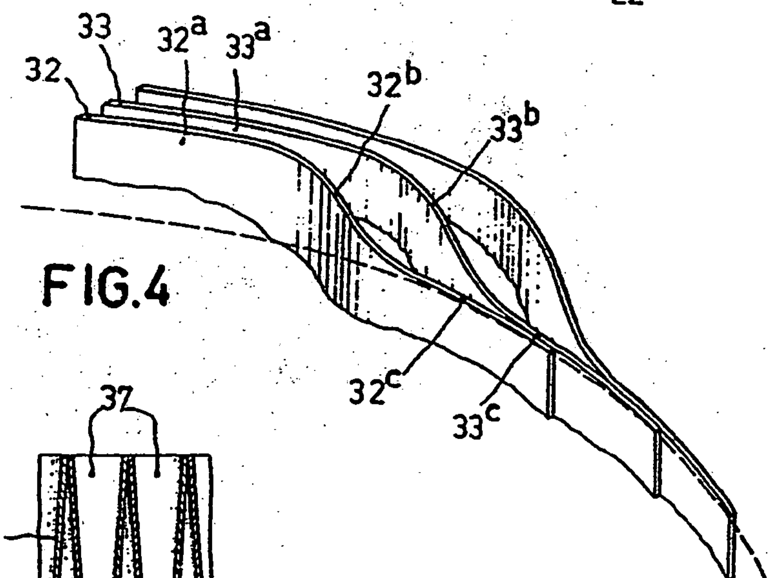


FIG.4

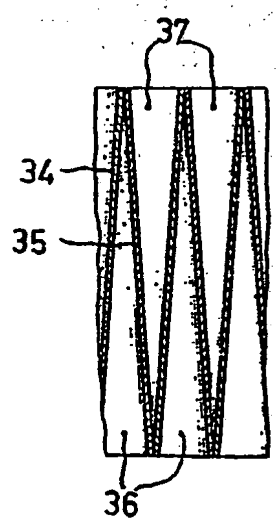


FIG.5

the side surface of the head 1 and is connected to an annular regenerator 5 encircling the head 1. For the sake of clarity only two heating tubes 4 with the associated apertures in the head are shown.

The medium of the hot-gas reciprocating engine which must be heated, flows through the heating tubes 4. As will be seen from Figure 1, the heating tubes 4 surround a substantially cylindrical chamber 6 which is the combustion chamber of the reciprocating engine. At the upper end 7 of this chamber provision is made of a number of burners 8 which direct their flames 9 to the centre of the combustion chamber to provide a turbulent gas flow. Through a pipe 10 liquid fuel is supplied to the device and subsequently broken up into a fine mist in an atomizer 11 by means of a medium under pressure which is supplied through a pipe 12. The atomised fuel is supplied to a chamber 13, which is closed at the upper side by a domed body 14 and is bounded at the lower side by the upper surface 7 of the combustion chamber, and mixed in this space with the primary combustion air indicated by the arrows I. Through slits 11b formed in a sleeve 11a this air can enter the chamber 13. Then the fuel is mixed in the burners 8 with secondary combustion air indicated by the arrows II and produces the flames required to heat the medium. The igniting means are not shown.

The circle of heating tubes 4 is surrounded at the outside by a heat exchanger 15 in accordance with the invention. In the embodiment shown, this heat exchanger is supported by an annular body 16 made of refractory material and in turn supports a domed body 44 which is also made of refractory material.

A first construction of this heat exchanger will now be described more fully with reference to Figures 2 and 3.

In Figure 2, a chamber 17 within the heat exchanger corresponds to the chamber 6 shown in Figure 1. The inner and outer circumferences of the heat exchanger comprise walls 18 and 19 respectively. As will be seen from Figure 2, the chamber between the walls 18 and 19 houses a number of plates, three of which are shown in Figure 2 in full length, extending from the inner wall 18 to the outer wall 19. In Figure 3 those parts of the same plates 20, 21 and 22 which lie closest to the inner wall 18 of the heat exchanger, are shown to an enlarged scale in a perspective view. Each plate comprises an intermediate portion 20^a, 21^a and 22^a, respectively, which here extends substantially at right angles to radii of the walls 18 and 19 and is shaped in the form of an Archimedean spiral. By way of fold lines the intermediate portions 20^a, 21^a and 22^a merge through bends 20^b, 21^b and 22^b into portions 20^c, 21^c and 22^c, respectively. Through bends 20^d, 21^d and 22^d which extend parallel to one another and also to the above-mentioned sets of bends 20^b, 21^b and 22^b, these latter portions terminate in edge portions 20^e, 21^e and 22^e respectively, which parts extend along the inner wall 18 of the heat exchanger. As can be seen from Figure 3, the intermediate portions of the plates are provided with ribs 23 formed by rolling, which in the embodiment shown in Figure 3 protrude to the rear through a distance which determines the relative spacing a of the plates. Owing to the provision of these ribs between each pair of plates a plurality of parallel ducts are formed which each have a width a and a height b and are intended for conveying two media which are to be brought into heat exchanging contact. Similarly to the construction at the inner wall 18 of the heat exchanger the plates are provided near the outer wall 19 with portions 20^f, 21^f and 22^f which through bends terminate in edge portions 20^g, 21^g and 22^g respectively, which are located at the outer wall 19 of the heat exchanger.

When these plates, which are arranged in the correct relative positions, for example, in an assembling jig, are connected to each other, for example by soldering or welding, at the two end faces 24 and 25 of the resulting body (Figure 1), a body is produced which has considerable strength and nevertheless owing to the arrangement of the intermediate portions of each plate, is flexible at its inner surface so that this surface is capable of expanding relatively to the outer surface.

Ducts 26, 27, 28, 29 provided between the overlapping and offset end portions of the plates and shown in Figures 2 and 3, can be used as supply and discharge ducts for the media to be brought into heat exchanging contact. In order to ensure a highly intimate contact between the media passing in counterflow through the heat exchanger, these ducts alternately convey different media. Thus in the embodiment shown in Figures 2 and 3 the duct 26 at the lower end of the heat exchanger will be fed with hot combustion gases, through orifices from the combustion chamber. These pass through the heat exchanger from its inner wall 18 towards its outer wall 19 into the chamber 28 and then leave the heat exchanger through orifices at the upper end through a duct 30^a and are discharged through a flue 30 (Figure 1). The combustion air to be preheated is admitted at the lower end of the heat exchanger into the duct 29, flows through the heat exchanger from the outside to the inside and leaves it at its upper end through the duct 27. Here this preheated combustion air is divided in the above-mentioned air stream I which serves as the primary combustion air and in a stream II which acts as the secondary combustion air.

For closing the ducts alternately at the upper and lower ends use is made of flat metal rings 31 (Figure 1). These rings have

alternate solid parts and apertures and can be secured to the heat exchanger by not completely removing the ring portions which form apertures but bending tongues, formed by these partially punched out portions, through 90° from the plane of the rings and introducing the tongues thus formed into the upper and lower ends respectively of the ducts 26, 27, 28 and 29 so that the rings are firmly secured.

The plates may be formed in shapes different from those shown in Figures 2 and 3. As is shown in Figure 4, the intermediate portions 32^a and 33^a of plates 32 and 33 may extend substantially similarly to the corresponding parts shown in Figures 2 and 3, but the transitions to portions 32^b and 33^b and to end portions 32^c and 33^c are smoother. Alternatively the intermediate portions of plates can be caused to extend more radially, which generally will result into the heat exchanging ducts being shortened.

As is shown in Figure 5 for a heat exchanger having a smaller longitudinal dimension, fold lines 34 and 35 may alternatively converge or diverge so that at the inner and outer walls ducts 36 and 37 formed between the bent portions and the edge parts are already closed by the relative arrangement of these fold lines.

WHAT WE CLAIM IS:—

1. A heat exchanger comprising an annular main chamber formed between substantially cylindrical inner and outer walls and housing identical closely-spaced metal plates each extending substantially throughout the length of the main chamber having overlapping off-set end portions each secured at one end to the inner wall and at the other end to the outer wall, supply and discharge ducts for media extending in the longitudinal direction of the main chamber being formed between the overlapping off-set end portions of the plates adjacent the inner wall at one end of the plates and between the overlapping off-set end portions adjacent the outer wall at the other end of the plates, media in further ducts formed between portions of the plates intermediate the end portions being in heat exchanging contact with one another through the plates, in which the further ducts are formed by projections on the plates in the form of ribs which extend substantially at right angles to the longitudinal direction of the supply and discharge ducts.

2. A heat exchanger as claimed in Claim 1, in which in a cross-section of the heat exchanger taken at right angles to the longitudinal direction of the main chamber the intermediate portion of each plate extends substantially at right angles to radii of the inner and outer walls.

3. A heat exchanger as claimed in Claim 1 or Claim 2, in which the intermediate portion of each plate is shaped substantially according to an Archimedean spiral.

4. A heat exchanger as claimed in any of the preceding claims, in which each end face of the heat exchanger is provided with at least one substantially flat ring which is disposed over orifices leading to or from the supply and discharge ducts, alternate orifices being open and closed by alternate apertures or solid parts of the ring respectively.

5. A heat exchanger as claimed in any of the preceding claims, in which the metal plates comprise sheet material provided with fold lines at the extremities of the intermediate portion of each plate, an adjoining bent portion and/or an adjoining end portion diverging or converging so that the supply and discharge ducts provided at the inner and/or outer walls of the heat exchanger are alternately closed at either end face of the heat exchanger.

6. A heat exchanger substantially as herein described with reference to Figures 1 to 3, Figures 1 and 4, or Figures 1 and 5 of the accompanying drawings.

7. A hot-gas reciprocating engine as herein defined provided with a heater and burner, the heater comprising elements which are disposed within a substantially cylindrical combustion chamber and in contact with ignited gas which flows past said heater elements, in which the heater elements are disposed in a circle within the combustion chamber which is in turn surrounded by a heat exchanger as claimed in any of the preceding claims and in which comparatively cold combustion air is supplied to the supply ducts of the heat exchanger situated adjacent the outer cylindrical wall at the end of the heat exchanger which is furthest from the burner, this air leaving the heat exchanger through the discharge ducts which are situated adjacent the inner cylindrical wall of the heat exchanger at the end of the heat exchanger adjacent the burner, while the exhaust gases of the burner pass over the heater elements through orifices cut of the combustion chamber and enter the heat exchanger through the supply ducts provided at the end of the heat exchanger furthest from the burner adjacent the inner wall of the heat exchanger and leave the heat exchanger through discharge ducts disposed adjacent the outer wall of the heat exchanger through orifices in the end face nearer the burner.

8. A hot-gas reciprocating engine as claimed in Claim 7, in which one end face of the heat exchanger is supported by a ring of refractory material while its other end face supports a dome-shaped body which substantially consists of refractory material and acts as a support for the arrangement supplying fuel to the combustion chamber.

9. A hot-gas reciprocating engine as claimed in Claim 7, substantially as herein described

with reference to Figure 1 of the accompanying drawings.

T. D. THREADGOLD,
Chartered Patent Agent,
Century House, Shaftesbury Avenue,
London, W.C.2,
Agent for the Applicants.

Leamington Spa: Printed for Her Majesty's Stationery Office by the Courier Press.—1962.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

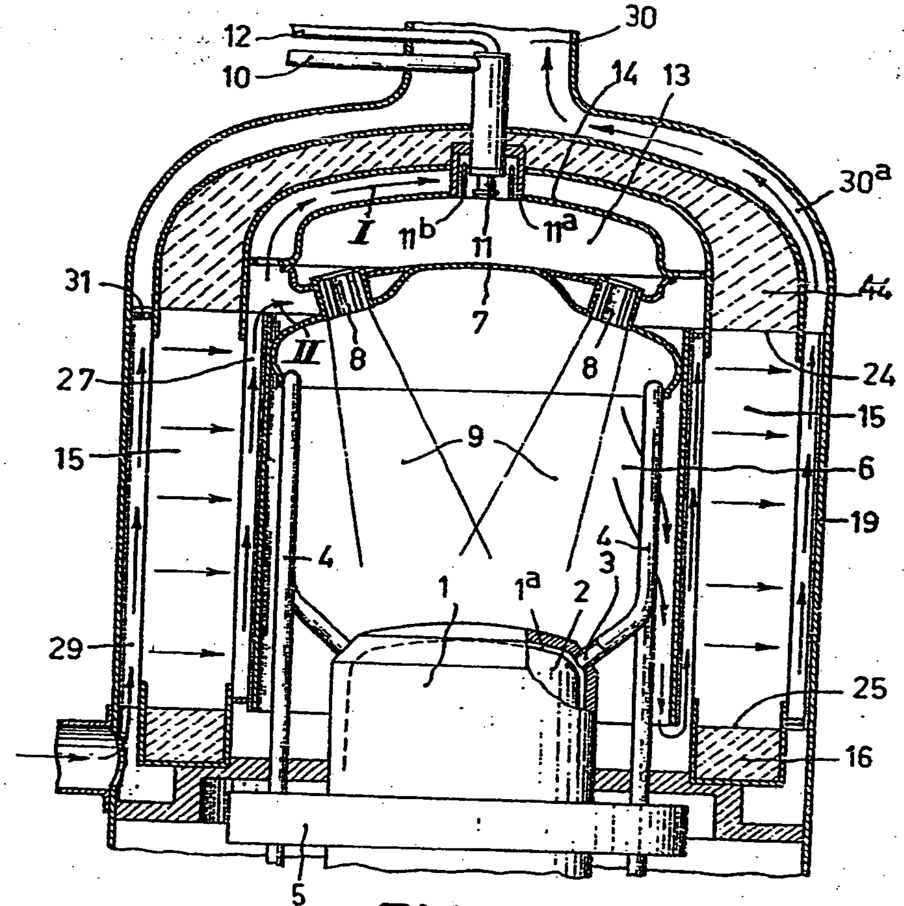

12
10
30
14
13
30a
I
11b
11
11a
31
44
7
8
8
II
27
24
15
9
6
15
19
4
4
3
1a
2
1
29
25
16
5

FIG.1

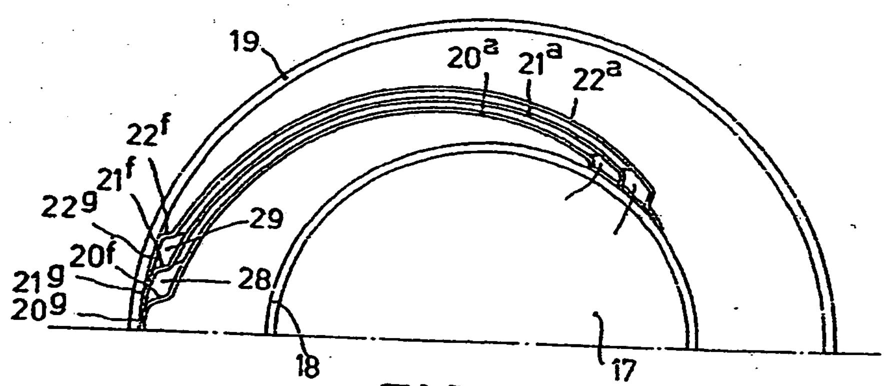

19
20a
21a
22a
22f
21f
22g
29
20f
21g
28
20g
18
17

FIG.2